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INTRODUCTION

TREES

LIVESTOCK

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RESOURCES

Silvopasture

Establishment & management
principles for pine forests
in the Southeastern United States

Silvopasture: Establishment & management
principles for pine forests in the
Southeastern United States

February 2008

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retired U.S. Forest Service researchers
Cliff Lewis, Henry Pearson, and Nathan Byrd.

Your vision and dedication to improving
forest and range management are the strong
roots that support the advancement of
silvopasture management today.

Background

This guidebook was created with the hope of improving the value of silvopasture training in two ways: it will be available for use during training sessions and will serve as a concise field companion when planning future silvopastures.

The information and principles contained in this initial printing have been reviewed by researchers and natural resource experts. It is anticipated that future versions of the guidebook will incorporate recommendations that result from actual field use and from training sessions.

About the editor

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Introduction

Silvopasture is an agroforestry practice that integrates livestock, forage production, and forestry on the same land management unit. Silvopasture systems are deliberately designed and managed to produce a high-value timber product (such as sawtimber) in the long term while providing short-term annual economic benefit from a livestock component through the management of forage or an annual crop component.

Well-managed silvopasture systems may also:

- Improve overall economic performance of a farm enterprise through diversification and maintaining biodiversity
- Maintain or increase tree growth
- Improve cool-season grass production
- Allow warm-season grass production with careful canopy management
- Provide shade for livestock
- Produce pine straw for landscaping and mulch
- Aid in erosion control
- Increase wildlife populations
- Improve water quality and water holding capacity
- Increase opportunities for recreation
- Enhance aesthetics and property values
- Provide habitat for turkey and quail

Is silvopasture for you?

Silvopasture is a management option by which landowners can realize diverse income-generating possibilities from the same acreage. A primary goal of a silvopasture system is to produce high-quality timber

in the long term while grazing or browsing livestock on the same acreage in the short term.

Traditionally, forest landowners who have managed southern pines could count on income derived from periodic thinnings of their stands for pulpwood while they waited for these stands to grow into higher-value sawtimber. However, over the last several years, the prices for pulpwood have decreased as many domestic mills have closed or shifted production. If this trend continues, traditionally densely established pine plantations will not be the most cost-effective forest management system as acreage is tied up in lower value trees that are eventually removed anyway.

For silvopasture, the landowner is establishing and producing trees with the goal of harvesting primarily for sawtimber and establishing forage to reduce the



The annual income from grazing and the long-term profits from trees respond to different market pressures and reduce risk when combined in the same operation.

need to purchase feed, thus optimizing land use by producing intermediate and long-term benefits. Landowners must be prepared to engage in some management of both tree and forage components over time as silvopasture is not a “plant it and leave it” system.

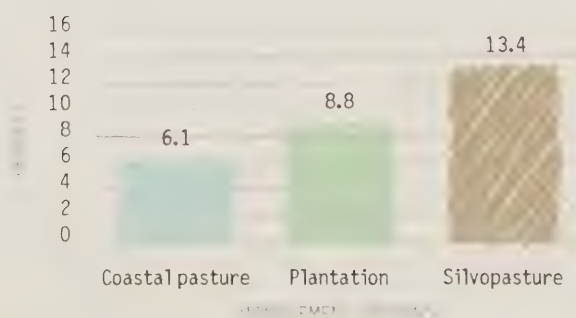
Economic considerations

Integrating trees, forage, and livestock creates a land management system to produce marketable products while maintaining long-term productivity. Economic risk is reduced because the system produces multiple products, most of which have an established market. Production costs are reduced and marketing flexibility is enhanced by distributing management costs between timber and livestock components.

Before a new silvopasture system is established, the landowner should explore thoroughly their economic and environmental considerations along with local land use, zoning, cost-share program, and tax regulations. Forest and agricultural land may have separate zoning and land-use regulations accompanied by different tax assessments. Environmental requirements (e.g., planting trees, stream-side protection, wildlife habitat maintenance) also may vary with land use.

Silvopasture systems can be established on any land capable of simultaneously supporting trees and forage. Silvopasture systems can require a relatively large land base to sustain timber and livestock production continuity. Typically, silvopasture systems have been established on existing pasturelands by planting single or double rows of trees with forage corridors between

Silvopasture has a higher internal rate of return compared to some other management options.





The Natural Resources Conservation Service in some states lists silvopasture as a practice that can be cost-shared under the Environmental Quality Incentive Program.

them. Silvopasture systems have also been established from existing stands of trees by thinning the forest to a desirable level to support forages or by removal of all trees in a designated area to create corridors or alleyways.

Initial establishment costs to consider

Before jumping into silvopasture, there are some cost considerations:

1. Site preparation
 - Clearing the site—either mechanically or with herbicide (cost of equipment + labor + cost of herbicide)
 - Tilling or plowing rows for tree planting
 - Soil sampling and fertilizer amendments (if necessary)
2. Seedling cost
3. Labor associated with planting
4. Fencing (permanent or temporary, electric high-tensile or portable polywire, solar or traditional)

5. Establishing fire-breaks (if fire will be a management option)

Typically, the cost for establishing a silvopasture system in an existing pasture that does not involve extensive site preparation should be about \$100 to \$150 per acre.

Long term economic considerations

- Tax value classification of system: Does your system qualify for tax breaks?
- Yearly cost for annual crop/forage establishment (seed, herbicide, labor, equipment, etc.)
- Fence maintenance
- Livestock management expenses
- Watering facilities/structures for livestock
- Fertilizer amendments (for forage and/or trees)
- Labor costs for pruning (see section on pruning)

Planning & establishment considerations

Southern pines—loblolly (*Pinus taeda*), longleaf (*P. palustris*), and slash (*P. elliotti*)—are compatible with forage production and livestock grazing when properly managed.

While a number of hardwood species have been successfully incorporated into silvopasture systems with grazing animals, these species typically take a longer time to establish and reach maturity, thus increasing the rotation period between timber harvests for the landowner.



Current silvopasture systems primarily involve cattle, sheep, and goats. However, other potential choices include horses, turkeys, chickens, ostriches, emu, rhea, or game animals such as bison, deer, elk, and caribou.

Livestock must be intensively managed in silvopasture systems. Timing and duration of grazing, stocking rates, and carrying capacity of the pasture must be carefully monitored to maintain site quality and tree seedling survival by minimizing damage to seedlings by trampling and rubbing, and preventing overgrazing and soil compaction. Depending on the density and growth rate of forage, livestock must be rotated between “pastures” to sustain growth and productivity of forages. A comprehensive grazing management plan—fencing or paddocking, periodic burning, rotational grazing, fertilization, placement of watering and/or supplemental feeding areas—must be implemented to maintain a silvopasture system.

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The Tree Component

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Arrangement & design

Common types of planting arrangements



SINGLE-ROW PLANTINGS consist of trees spaced about 8 to 12 feet within the row and 16 to 30 feet between the rows. Closer spacings restrict some equipment accessibility and can potentially reduce forage production if trees are not thinned and pruned in a timely manner. The wider row spacing tends to favor forage production over closer tree spacing.



DOUBLE-ROW PLANTINGS stagger tree rows with 8 to 10 feet between trees and rows. Once established, both forages and trees co-exist and can contribute to a highly productive silvopasture system. When setting the alley width, consider the width of the equipment that will be used in the management of the forages and plant the width of the alleys accordingly.

There seems to be no disadvantage to planting in double rows compared to single rows, although single-row plantings seem to exhibit less tree-to-tree competition. Research shows that legumes under the pine canopy perform better than legume forage in open areas.

MULTIPLE-ROW SPACING has two to three rows of trees at a fairly close spacing (8 feet x 10 feet or 10 feet x 10 feet) with an alleyway of 20 to 40 feet between sets of tree rows for forage production. Some feel this system tends to favor ease of forage and timber management and forage production systems.



While TRIPLE AND QUADRUPLE ROWS have been used in a silvopasture system, it has been found that trees in the middle rows typically grow more narrow and are of poorer quality the outer rows of trees out compete them for sunlight and soil nutrients. Thus, double row systems are considered optimal.





BLOCK PLANTINGS are evenly spaced planting arrangements with wider spacings than a traditional forest plantation. A typical silvopasture block planting would have trees on a 12 feet x 12 feet or 15 feet x 15 feet spacing. Some feel that this system favors timber production. Forages are more sensitive to canopy density and timely thinning must be conducted to maintain forage production.



FORAGE / HAY PRODUCTION: During the first 2 to 4 years, forage can be used for hay. Therefore, it is important that the row spacing is planned to fit the haying equipment that will be used. So, be patient with the establishment of the system and it will function and be a productive system throughout the whole rotation.

Tree pattern

Trees should be established or spaced to optimize growing space and light penetration for high-quality saw logs and forage. Forest sites may require thinning and some tillage to provide a favorable seedbed for

germination and growth of selected forages. On pasture sites, weed/forage suppression and competition control (through subsoiling, herbicides, tillage, and/or mulch) may be required for 2 to 3 years to establish tree seedlings but must be carefully selected to avoid damaging desirable plants.

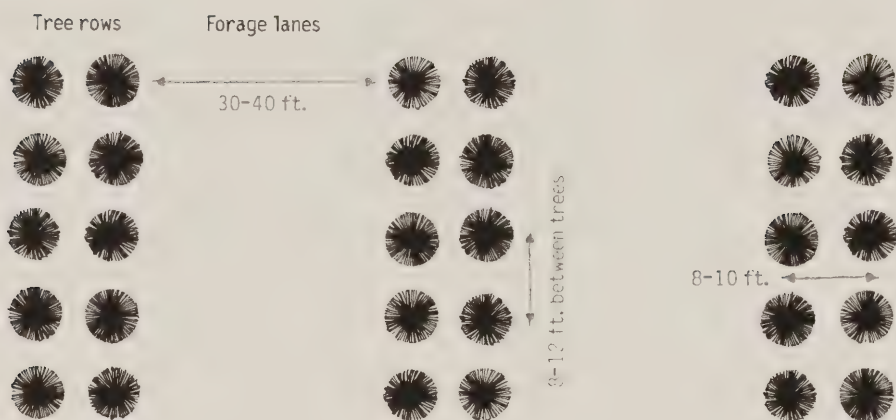
Spacing & stand density

For commercial conifer plantation establishment, four to six times as many trees are planted than will be harvested at the end of the rotation. This practice traditionally provided close spacing that encouraged self-pruning. Canopy density in a silvopasture system is generally managed between 25 to 60 percent, which

Shade from trees lengthens the forage growing season and improves forage quality. The shade also increases the comfort level for livestock which reduces stress. Additionally, the structure and plant diversity is attractive to many wildlife species including wild turkey, quail, deer, and many songbirds.



provides larger open spaces for forage production and management. Tree diameter growth in lower density stands is accelerated due to reduced competition. Trees planted in rows often perform poorly if they do not have at least one side in full sun. Therefore, for maximizing growth, single or double rows are generally preferred over triple or multiple rows of trees.



The planting arrangement for the tree component of silvopasture may change depending upon the landowner's objective in achieving timber and forage growth and wildlife habitat. It can also influence production costs and equipment accessibility. However, a healthy tree stocking range for silvopasture establishment is typically between 200 to 400 trees per acre.

The number of trees per acre will dictate the number of thinnings that will need to be carried out and the types of products that will be produced (e.g., poles, chip-and-saw lumber, or sawtimber). At 150 to 200 trees per acre, only one thinning may be necessary well into the rotation (20 years) to remove poles or saw/veneer quality logs and provide additional space for 10 more years of growth for the high quality saw logs that are left.

For landowners managing hay or other crops between rows of trees, appropriate management considerations must be made, such as suitable width of alleys (for planting and harvesting equipment) and chemical compatibility of herbicides and pesticides.

Site preparation

There are several operations that should be considered when planting tree seedlings into an existing pasture to ensure good tree survival. Mowing or close grazing of grass residue is helpful to remove debris that may hinder planting, especially machine planting.

For establishment on existing pasturelands, the use of herbicides or tilling is recommended to remove competition and establish suitable rows for tree planting. This improves the ease of planting and improves rooting conditions for young seedlings, thus insuring better growth and survival.

In some areas, a prescribed burn in the late fall or pesticide treatment may be needed to control rodents prior to tree planting. Follow-up treatments with a

Apply a herbicide or till a strip 2 to 4 feet wide for each row of trees to be planted. If the soil has a compacted layer, rip or subsoil down the planting rows to loosen soil.



selective herbicide may be needed for 2 to 3 years until trees are well established.

Subsoiling is highly recommended when planting into pasture due to the potential compaction that may be present from many years of grazing. Subsoiling must be done on the contour or water erosion following the

sub-soiling channel will blow the trees out of the ground. Generally sinking the shank and ripping to a depth of 18 to 24 inches is adequate to eliminate compaction layers and improve water infiltration. Disking is sometimes used to help break up the sod and incorporate some herbicides.



For compacted soils, a typical single shank sub-soiler mounted on a tool bar should suffice for soil preparation.

Tree planting guidelines

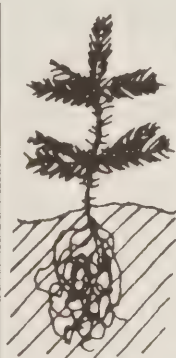
Seedlings should be stored in a shady place and roots kept moist until planted. Trees can be planted with a mechanical planter or by hand with a dibble bar, hoedad, or shovel. Maintaining straight rows and uniform spacing are important considerations for silvopasture. If the area to be planted is sloped, make sure to plant along the contour of the site.

When planting bare-rooted seedlings, make sure the root collar (the area between the seedling's roots and stem) is even with ground level. Seedlings that are planted too deep, too shallow, or "J-rooted" (pushed into the ground with the tap root facing up) might not survive. After planting, soil should be packed around the seedling. For longleaf pine, soil should not cover the terminal bud.

Seedling success depends on proper planting



Correct way



Tangled roots



Air pocket



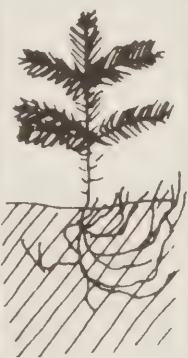
Too deep



Too shallow



Rocks



Turned-up roots

After planting, exclude livestock until the trees grow beyond the browse line. In the South, that is generally 3 to 4 years depending on productivity of the site. Livestock do not consider southern pines a preferred food; however, if pasture is not adequate or they are deprived of minerals, browsing on trees will occur. Also, make sure the main stem is resistant to breakage. This may be a problem, especially with longleaf pine, and the livestock may need to be deferred for an additional year.

Species

Genetically improved tree seedlings are preferred for establishment of silvopastures. It is especially important to use fusiform rust resistant seedlings if slash or loblolly pines are planted. Large seedlings grown at low density in a nursery have much more desirable root characteristics than smaller diameter seedlings grown in crowded nursery beds. Well-developed, fibrous root systems speed up successful seedling establishment. Bare root seedlings are cheaper than containerized trees, but they need to be planted during winter. Containerized seedlings work well, especially for longleaf pine, and they can be planted either during the winter or after summer rains begin. Refer to local planting guides for specific recommendations on planting times.

Ideal pine species for silvopasture include:

- **Loblolly pine (*Pinus taeda*):** Loblolly pine is the most commonly planted commercial yellow pine species in the Southeast and typically has the fastest growth of the pine species. Loblolly is suitable to plant in well drained upland areas or clay soils. Loblolly typically requires more frequent pruning as it has more branches and produces more shade than the other southern pine species. There are a number of improved varieties of loblolly pine currently available to reduce rotation length.
- **Slash pine (*Pinus elliotii*):** A good self-pruner, grows well in moderate- to poorly-drained sandy soils. Light canopy cover produces less shade. Slash pine is commonly planted throughout the Coastal Plains of Florida, South Carolina, Georgia, Louisiana, and Alabama. However, with smaller branches, slash pine is susceptible to ice damage which should be considered in more northern latitudes.

- **Longleaf pine** (*Pinus palustris*): Much of the Southeastern United States used to be naturally covered in Longleaf pine. Due to over harvesting, replanting to loblolly pine, and fire suppression, there are few remaining natural stands. Longleaf has the highest value timber of the southern pines, but traditionally required the longest rotation length due to the “grass-stage” that seedlings may remain in without proper burning or use of herbicide to “release” the trees from this stage. New herbicides are available to release longleaf from this grass stage within one year. Longleaf can be planted in upland or wetter sites. Containerized seedlings are highly recommended for longleaf pine.

Seedlings

Seedlings can be purchased through commercial nurseries or from a State-operated nursery. Many State forest agencies maintain nurseries to supply private forest landowners with seedlings.

Herbicides

Weeds and woody brush may be suppressed by browsing, mechanical treatment, or chemical herbicide application. A common approach to planting trees in established pastures is spraying a strip or circle around trees to provide a 4- to 6-foot diameter “competition-free zone” around each tree until the root system and canopy of the seedlings are well established.

Young seedlings are affected by the vigorous root system of forage grasses. There is concern that fescue could be toxic to trees in the seedling stage. It is highly recommended that an extra wide strip of herbicide application be used during establishment of trees into fescue.

Here are a few of the common herbicides used for herbaceous weed control during tree establishment:

- **Arsenal®**: common forestry herbicide used to control grasses and weeds throughout the rotation of pine plantations.
- **Stinger®**: primarily used in seedbeds of southern pine to control a number of broadleaf weeds.
- **Accord®**: when used with Oust, controls many broadleaves, grasses, sedges, and suppresses brambles/blackberries.
- **Roundup® Ultra**: controls perennial weed growth during plantation establishment of pines.
- **Velpar®**: effective for contact and residual control of many annual and biennial weeds and woody plants. May be sprayed in wet areas.
- **Oust®**: pre- and post-emergent herbicide. Commonly applied with fertilizer treatment before seedling establishment.
- **Fusilade®**: for post-emergent control on grassy weeds.

If herbicides are used, special attention must be paid to all environmental hazards and site-specific application criteria listed on the herbicide label and contained in Extension and crop consultant recommendations.

- **Oustar®:** broad-spectrum contact and residual herbicide. Requires rain/soil moisture to be absorbed into root systems of weeds.

Scalping is highly recommended when planting into sod (especially for longleaf pine). Because grass is such a tough competitor for young seedlings, a herbicide strip 4- to 6-feet-wide per tree row is recommended for most grasses with a strip 8 feet wide, or wider for very aggressive grasses, such as bermudagrass.

This conifer plantation was installed using scalping attachments on the tree planter to peel back the sod and create a furrow into which the seedling was planted. When scalping or ripping, it is important to follow the contour of the land to avoid erosion.



There are many herbicides on the market. An applicator's permit is required for many agricultural herbicides. Make sure the herbicide used is compatible with the tree species and local conditions, and approved for the target herbaceous weeds.

Pruning

The ultimate goal of timber production in a silvopasture system is the production of high-quality sawtimber. Widely spaced trees delay canopy closure which benefit forage crops by allowing more sunlight to reach the ground. However, open grown trees tend to develop a greater taper and larger side branches that can reduce wood quality (through larger knots) if trees are not pruned.

Pruning is a necessary part of a profitable silvopasture system. The object of pruning is to confine the knots produced by these branches to a small diameter, thereby producing higher quality, knot-free wood on the outer diameter of the tree stem. An 8 feet x 8 feet x 40 feet stocking would likely produce knots that are slightly larger (on average) than a more dense square spacing (i.e., 10 feet x 10 feet). However, at a given stocking, rectangular spacing might not affect other traits of loblolly pine. Pruning has the added benefit of raising the tree canopy which allows more light to hit the ground, thus providing higher production potential for the pasture element of the system and producing an aesthetic open environment.

The following guidelines provide steps for pruning in a silvopasture system:

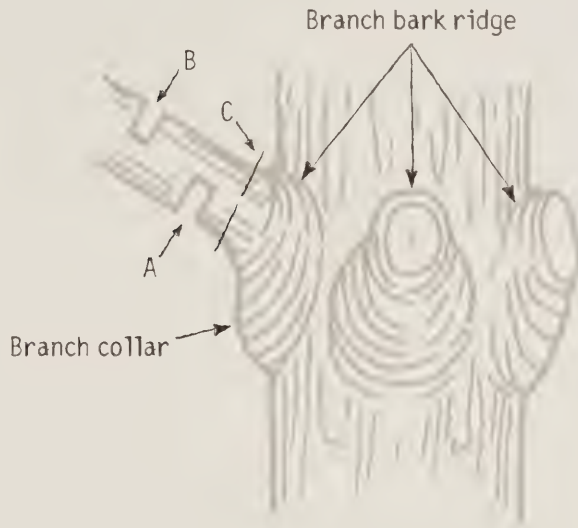
- Pruning should be initiated when the trees reach 15 to 20 feet tall and/or the diameter of the tree reaches 5 inches at a height of 6 inches above the ground.
- Pruning should remove all of the branches where the trunk diameter is > 4 inches but never more than one-third to one-half of the total crown. Maintain a live crown equal to one-third of the tree height.
- This is repeated as the tree grows until you have the desired height of 18 to 32 feet. While pruning has

traditionally been carried out to a bole (trunk) height of 16 feet, it has been shown that remaining branches tend to create larger knots in the remainder of the tree stem. If pruning equipment is

Where to prune

All pruning cuts should be made outside the branch bark ridge.

- Small branches, < 2 inches in diameter, may be pruned with a single cut along line C.
- Larger branches should be pruned using a 3-cut method.
- The partial undercut, A, prevents the bark from peeling away from the trunk as the second cut, B, is being completed.
- After the weight of the branch is gone, remove the remaining stub with the third cut, C, without injuring or cutting the branch collar.

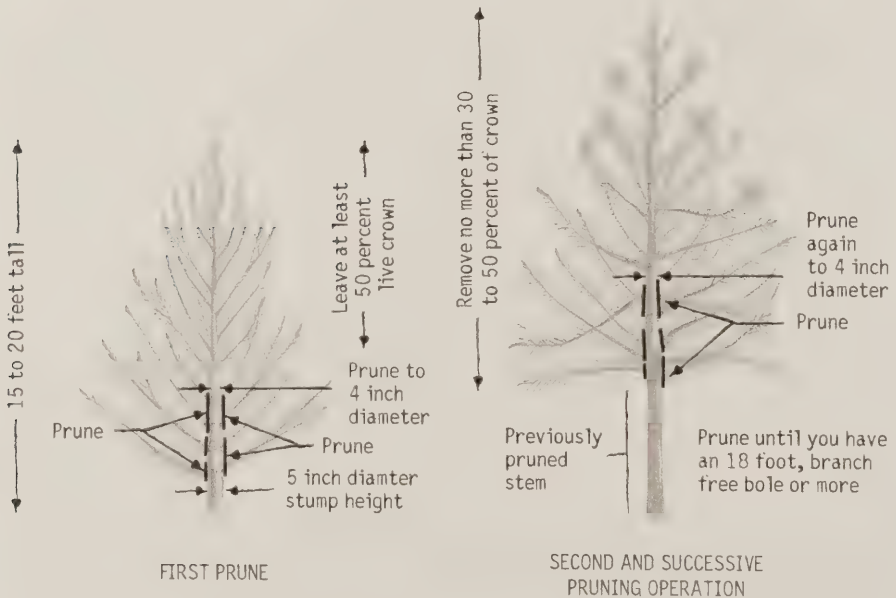


available, it is recommended to continue pruning to a height of 32 feet—thereby producing high quality, knot free wood on the outer diameter of the tree stem with only a 4- to 5-inch defect core.

- The best time to prune living branches is late in the dormant season (winter) or very early spring before active tree growth begins.
- The fastest and most economical way to prune trees for maximum quality is by using a lopper or lopping shears. Most loppers can effectively prune branches that are 2 inches or less in diameter.
- Never prune with a machete. Using a machete, while quicker, can cause irregular breakage of limbs and create excessive wounds to the tree.

Canopy management

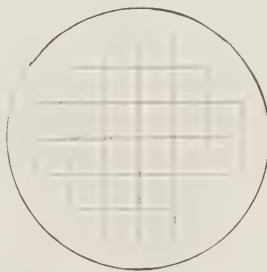
The tree canopy is managed for between 25- to 45-percent canopy for warm season grasses and 40- to 60-percent canopy for cool season grasses. This management scheme will require thinning at intervals of approximately every 5 to 7 years depending upon site productivity to keep the canopy within the desired range. If canopy begins to exceed the desired amount, forage production will begin to decline. If the plantation has been in forest for a significant time there will probably be a plethora of vegetation besides the desired grasses that begin to grow. Management of the understory vegetation is a must using chemical or biological control to favor the desired forage species. If the plantation never had forage grass established on the acreage, grass and or legumes may have to be established to get the desired vegetation.



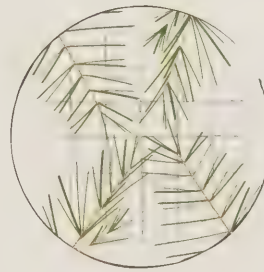
In most cases, individuals use an ocular estimate to determine the canopy percentage. It is hard to prove whether the ocular estimate is right or wrong, but it has been shown difficult for two people to obtain a similar answer. One tool that helps maintain consistency in the canopy estimate is the spherical densiometer. Hold the instrument level, 12 to 18 inches in front of the body and at elbow height, so that the operator's head is outside the mirror grid area.



Depending on the model, the densiometer will contain a concave or convex mirror with a grid on it.



While there are no dots on the grid assume four equal spaced dots in each square on the grid.



Systematically count the dots that are covered by leaves, stems, or branches. Multiply the total count by 0.96 to obtain the percentage occupied by vegetation or percent canopy. Assuming each dot represents 1 percent is generally considered accurate enough.

Wood quality

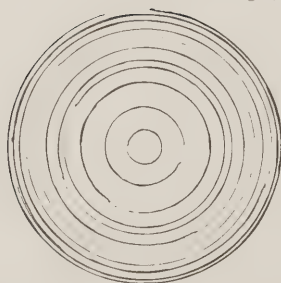
Wood quality—that is, density, strength, and ultimately, value—is commonly thought to be compromised with fast growing trees from wide-spaced plantations. The misunderstanding is that fast growing trees have a higher percentage of juvenile or core wood that is less dense and weaker. In fact, other factors, such as species, percentage of summerwood, and age affect wood characteristics far more than spacing and growth rate.

It is tree age, not growth rate, that most significantly affects wood density of southern pines. This fact is sometimes misunderstood because fast growing trees can reach harvestable diameters at an earlier age. It is these younger trees that have a higher proportion of less dense juvenile wood. However, if these widely-spaced, fast growing trees are harvested at the same age as closely-spaced, slower growing trees, the wood density is nearly the same. In fact, 32-year-old slash pines that

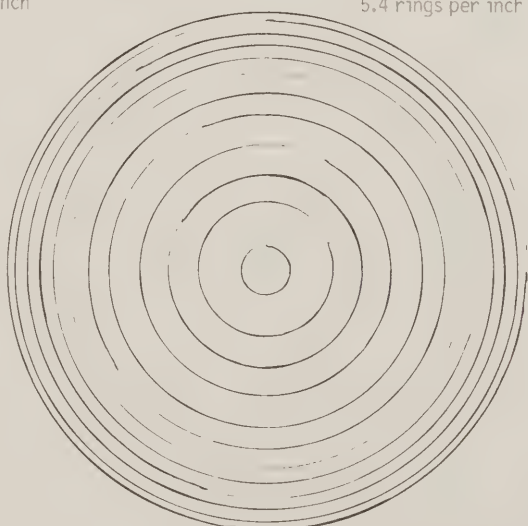
Proper tree pattern will produce larger logs. For stumpage, size is valued more than number of rings per inch.



6 feet x 6 feet
\$7 per ton
Pulpwood
9.6 rings per inch



8 feet x 8 feet
\$28 per ton
Chip 'n' saw
7.8 rings per inch



15 feet x 15 feet
\$46 per ton
Sawtimber
5.4 rings per inch

Effects of spacing on wood properities

30-YEAR-OLD LOBLOLLY PINE IN PIEDMONT OF SOUTH CAROLINA	8' x 8' not thinned	8' x 8' thinned	12' x 12' not thinned	12' x 12' thinned
Core wood diameter	6.0"	6.0"	7.7"	7.7"
Diameter at breast height (d.b.h.)	9.0"	10.0"	11.3"	12.9"
Rings per inch	6.2	5.6	4.9	4.3
Basal area in core wood	44%	36%	46%	36%
Sawlogs (tons per acre)	15	37	68	76
Specific gravity	0.46	0.51	0.47	0.50

Sawlog data and thinning values were produced from a growth and yield program where half of the trees were row-thinned at age 14 years.

were planted 15 feet apart might have a smaller percentage of core wood in the first sawlog than trees spaced 6 or 8 feet apart.

It is true that trees grown in more widely spaced configurations have fewer rings per inch and greater diameter of core wood. However, wide spaced loblolly pine trees have a higher specific density and yield greater tons per acre of sawlogs, than closely spaced trees, without increasing the total basal area of trees with core or juvenile wood.

The two most common measures of wood quality are: strength, Modulus of Rupture (MOR), and stiffness, Modulus of Elasticity (MOE). In both cases, tree spacing has been shown to have minimal affect on dimension lumber sawn from unthinned 40-year-old slash pine growing in the Georgia Coastal Plain.

All this being said, it is not a simple matter to market larger diameter, high quality silvopasture logs for a higher value. As pointed out by David South, Ph.D., "When log sizes are the same, many sawmills might not pay more per green ton for denser, older saw logs. However, a few specialty sawmills do not purchase younger, plantation grown pines that are known to

INITIAL STOCKING (trees per acre)	HARVEST AGE (years)						Influence of stocking on the percent of basal area in juvenile wood of loblolly pine.
	22	24	26	28	30	31	
	PROPORTION OF BASAL AREA IN JUVENILE WOOD (%)						
300	51	45	42	39	36	35	
600	53	49	45	42	39	38	
900	54	49	46	41	39	37	

produce wood that has a specific gravity < 0.48 . Therefore, it would be useful for landowners who operate their own portable sawmills to know how to produce denser wood when planting less than 500 pines per acre.”



The Livestock



Component

FORAGE

RESOURCES

Overview

Livestock provide income, consume weeds, and are one major tool by which grass/legume, and tree/forage competition is managed. Grazing may also reduce fertilizer needs by increasing the effectiveness of soil nutrients through recycling (in dung and urine) of elements such as nitrogen, phosphorous, potassium, and sulfur which are stored in pasture forage. Livestock may also be used for site prep by allowing them to “overgraze” areas with weed problems.

Trees in pastures provide shelter for livestock during periods of inclement weather. This can significantly improve animal performance during particularly hot or cold times of the year. In most cases, forage growing under the shady, low wind environment near trees tends to mature more slowly and, therefore, be lower in fiber and more digestible than that growing out in the



Goats can be incorporated into silvopasture systems.

open. Recently established systems may be grazed with little browsing damage to trees provided that other, attractive forage is present.

Conifers, although not really palatable to livestock, are most likely to be browsed after spring bud break when foliage is still light green in color. Livestock like variety in their diet. They will often consume a small amount



of tree foliage each day. This small amount of browsing may accumulate to unacceptable levels when animals are in the silvopasture for prolonged periods—which should be avoided by proper management. Age and experience of animals is probably more important than breed in predicting the willingness of livestock to browse or debark trees. Young animals and those with a past or learned experience of eating tree foliage are much more likely to browse trees. Browsing damage can sometimes be eliminated by removing or managing these animals. Browsing by livestock is unlikely to kill young trees unless it is both severe and repeated several times. Removing the top bud of conifer trees, or over half of the current year's foliage, however, will reduce tree growth that year.

Trampling of very young seedlings and livestock rubbing on tree saplings may be a problem, particularly with cattle. Where livestock damage must be avoided, young silvopastures may be hayed, or trees protected from livestock by electric fences, individual tree shelters, or rigid mesh tubes. Once the top branches of trees grow above the reach of livestock and a thick layer of bark has developed, potential for tree damage by livestock browsing is minimal and agroforests may be managed similar to pastures.

Grazing systems

Continuous stocking vs. rotational grazing

With a continuous stocking system, the animals are maintained on a single pasture or “all” pastures during the entire grazing season. However this does not mean the stocking rate (number of animals per acre) has to remain constant or that grazing on a particular piece of land will be season-long. This practice is not generally recommended for silvopasture systems. However, available forage can be effectively utilized by adjusting the livestock numbers up and down based on forage production.

While continuous stocking requires less fencing, watering facilities, and labor, the continuous selection by grazing decreases desirable forage species creating weedy pastures and areas of overgrazing and undergrazing. However, it allows livestock to selectively graze the most desirable or high quality plants, thus average daily gains can be quite good. It is the potential problems associated with continuous stocking that makes it the least desirable system with silvopasture. High impact areas can have detrimental impacts on tree growth and survival and lead to soil erosion. More intensive management and monitoring is required for this system.

Rotational grazing systems utilize recurring periods of grazing and recovery with animals being rotated among cells, paddocks, or pastures of a grazing management unit. The number of cells or paddocks may vary from only a few to 12 or more. A high stocking rate is imposed on a paddock for a short grazing period followed by a longer recovery or rest period.

Grazing periods generally range from 1 day to 1 week. It is important that the grazing period is not so long



that forage regrowth begins before the animals are rotated. If this occurs, animals will regrazed new growth, thus increasing the recovery period. The recovery periods, when the forage is regrowing, are longer and typically range from 2 to 5 weeks. Forage species as well as climate and soil resources influence this recovery period.

Paddocks

The optimum number of paddocks will vary from farm to farm, depending on the individual circumstances, resources, goals, environmental conditions, and desired level of animal production. Paddock numbers vary considerably, depending on need, desire, and resources. For most beef cattle grazing operations, 5 to 10 paddocks may be sufficient. This permits paddocks to be grazed in 3 to 7 days and rested 25 to 35 days. In most cases, five paddocks should be considered a minimum, and there is little economic advantage for most operators to have more than 12.

Know the productivity of the soils and forages and when possible adjust paddock size of less productive units so production is similar on each paddock. This will allow similar grazing periods per paddock. An important point for providing optimum nutrition to the overall herd is to have animals in appropriate groups. These groups would be gestation (dry cows), lactation (nursing calves), first-calf heifers, and replacement heifers. Each of these four groups has very specific nutrient requirements. If all of these animals are managed together, then most of the cattle are being over- or under-fed and very few are being fed to meet their requirements. Again, grazing management in a silvopasture system helps eliminate this problem. Because the animals are being grazed in specific pastures and not allowed access to the entire acreage



Diagrams show options for dividing up grazing area into paddocks. The blue circle indicate water sources and lines indicate fencing. Water sources should be portable where possible.

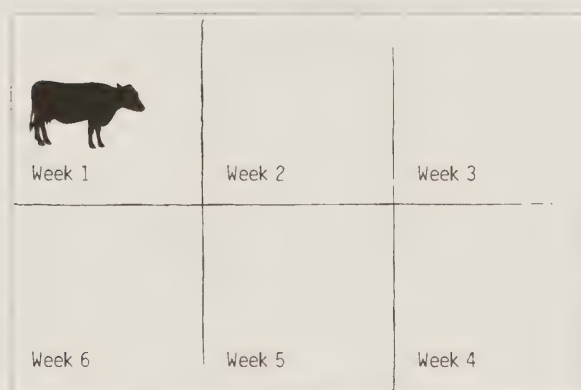
then it becomes easier to manage these groups. In fact first-calf heifers or grass-finished stockers should have first access to a fresh pasture to get the highest quality forage, followed by the lactating cows. The lowest quality forage would be cleaned up by the dry cows. Thus, silvopasture, grazing management, and optimal nutrition all become synonymous.



Managing rotational grazing system

Utilize the higher quality parts of the forage plants for grazing (top one-third of leaf). Do not force animals to eat low quality basal leaves and stems.

- Match rotation time to forage growth. Do not use a fixed time schedule.
- Maintain sufficient leaf area for photosynthesis.
- Rotate animals to a new paddock before they graze new regrowth.



- Forage quality decreases with increasing forage maturity and thus it is important to plan the entire management scheme around the forage program to take full advantage of forage quality when it peaks.
- Adequate mineral supplements are needed in silvopasture systems.

Where land allows, uniform sized paddocks with parallel sides can be desirable for rotational grazing systems. Uniform sized systems are sometimes implemented to better facilitate grazing distribution, the addition of subdivisions, as well as the mechanical

harvest of forage when appropriate. This is less critical for small paddocks or where the grazing period is generally 3 days or less. Cattle take about 3 days to establish a strong grazing pattern within an individual paddock. When cattle are allowed to remain on a paddock beyond 3 days, spot grazing (caused by low animal numbers and too large of an area) and pronounced cattle trails will begin to develop. When the cattle return to this paddock they will again begin to follow the grazing patterns previously established.

This rotational management plan incorporates 15 paddocks with streams and water impoundments for water sources. Additional water tanks would be necessary in the paddocks without existing water sources. Plant species composition and proper soil testing are also necessary for proper establishment and management.



Fencing

Because overgrazing reduces the nutritional composition for the animal and reduces the regeneration of forage, fencing is an important component of a silvopasture system. Fencing allows control of animal movement within a silvopasture system. Fence plans should be flexible and not limit grazing options. Three types of fencing are commonly used: perimeter fences, permanent subdivisions, and temporary/portable fences.

Energized high tensile wire fence will withstand falling debris. Strategically locate power switches to improve pasture access and diagnosis of power failures.



Proper pasture rotation using a paddock fencing system provides “recovery periods” for the grazed forage, minimizes soil compaction, and protects trees in a silvopasture system. There are several key components in an effective and easily managed fencing system:

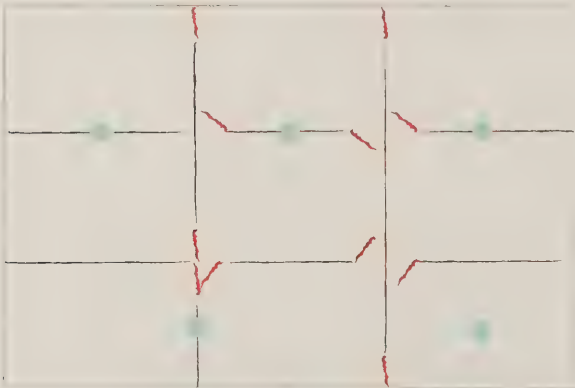
- An energized fence is primarily a psychological barrier and can only be effective if the fence carries enough current to deliver a “deterrent” shock. Soil type (rocky, sandy, or clay) and soil depth will need to be considered when planning and installing an energized fence. AC-powered units are generally the best choice for energizing a fence if 220 or 110 volt power is available. Battery powered systems with solar recharging capacity can be used onsite. A properly sized energizer should generally produce 1 joule per mile of fence needed.

- Fence should be properly grounded with a minimum of 3 feet of ground rod per joule output (typically provided by three, 96-inch ground rods, or other configurations in shallow soils, placed at least 10 feet apart). The fence should also be protected from lightning by installing a surge protector at the power source; a lightening choke may be installed “in” the fence, and an additional ground rod every 3,000 feet of fence.

Thoroughly consult with an energized fence supplier or livestock management specialist for specifications and site requirements for proper installation of an energized fence.

Gates and access

The location of gates in the rotational system is important to facilitate the movement of livestock through the paddock and the alignment of temporary lanes and alley ways.



Wires and wire spacing

High tensile wire is recommended when using electric fences for perimeter areas and in cross-fences. The number of strands depends on type of livestock, topography of the area being fenced, prior training, and management. Generally a minimum of four to six strands is recommended for perimeter fencing and one to three strands for cross-fencing, depending on livestock. For smaller livestock like goats, tighter configurations are sometimes needed.

If a land line is not available to supply electricity, a battery or solar powered system is required. Small units with less than 1 joule output may be powered by self-contained lantern batteries while larger units up to

An in-line switch is a wise investment. By strategically locating switches, a landowner can save miles of walking when tracing electrical current using a voltmeter.



9 joule output can be powered by 12-volt automotive batteries. Deep cycle RV batteries provide greater storage capacity and better recharge. The higher the output of the energizer, the more rapidly a storage battery is drained. To avoid repeated battery turnaround, a solar recharge system is a must. A number of solar panel systems exist on the market.

However, it is important to match the size and output of the solar system with the output of your energizer. A good rule of thumb is that allowing 1 mile of fence per joule output will give satisfactory performance in most situations.

Voltage requirements for livestock vary depending on the type of livestock. Generally accepted figures for adequate control are: 6,000 volts for cattle, 2,000 volts for sheep and goats, and 1,200 volts for hogs and horses.



A reliable energy supply is necessary for powered fences. Also, ensure that an adequate supply of water is available in each paddock.



Wire recommendations for livestock

See state guidelines and standards for more specific details

LIVESTOCK	NUMBER OF WIRES	WIRE HEIGHTS (inches)	POST SPACING (feet)
Cows with calf	1 or 2	28-34	40-80
Stockers	1 or 2	22-32	40-60
Sheep	3 or 4	5-10, 20, 32, 46	20-40
Cattle	3 or 4	10, 20, 32, 46	20-40
Cattle, horses	4-6	10, 20, 30, 40, 50	20-40
Sheep, goats	5-8	4, 8, 12, 18, 24, 30, 40, 52	20

Portable fencing

Polywire or polytape are the most commonly used materials for temporary or portable cross fencing for paddocking purposes or for allocating stockpiled pastures for winter grazing. Portable fencing is easily solar energized and grounded and commonly used for break and strip grazing. Both of these materials are combinations of plastic strands and metal filaments. These products are lightweight and require no setup tools. Minimal bracing is needed to hold the fence and very light duty lineposts may be used. Most polywire is sold in 6- or 9-strand. The 6-strand can be effectively energized for up to one-half mile. The 9-strand polywire has more wires and also slightly larger wire filaments that increase the practical length up to several miles.

Polytape has the advantage of greater visibility when compared to polywire. Tape tends to flutter in the breeze and attract more attention and recognition from livestock. Good quality tape lasts from 5 to 7 years, while polywire may last up to 10 years.



The number of wire strands depend on the type of livestock being grazed. Generally, a minimum of four to six strands is recommended for border fencing and one to three strands for cross-fencing cattle.

Plastic step-in posts are the most common linepost used with polywire and polytape products. As long as soil conditions allow, posts can be easily pushed into the ground or hammered in. On level or evenly sloping terrain, line posts may be up to 100 feet apart for a single wire paddock fence. Most conditions however, will require a more realistic 40- to 60-foot spacing. Three or more wire fencing systems will require a closer spacing. Most fence post spacings range from 20 to 60 feet between posts. To use the polywire and polytape systems effectively, a reel system is a must. Features of a good reel system include a positive locking system, a good warranty, the capacity of the reel to hold the amount/length of product used, and high-speed gearing when necessary.

Watering

Grazing animals need to drink on a regular basis and to do this they must stay within a certain traveling distance of the water source. Consumption of water is greater when water is made available in every paddock and the travel distance is kept < 800 feet. When water is located close by (< 800 feet) from where the cattle are grazing, they will water as individuals and not a herd. Pasture utilization tends to become less uniform as cattle travel more than 800 feet to water. If adequate watering facilities are limited, use lanes and alleyways to get to a single water source serving several paddocks; mud and trampling around the water source can occur.

Producers generally desire to have one water source serve more than one paddock. Placing the water tank in the fence line toward the center of the paddock allows a wider area of access and keeps compaction and animal concentration to a minimum. It also provides

Portable tanks are easily removed during timber harvesting.



the opportunity to cross-fence if the producer needs to increase the intensity of the grazing system. While water sources are commonly located in the middle of the grazing unit, it is best to have flexibility and portable water facilities to better manage vegetation, reduce trampling, and allow transport of tanks. Rubber or nylon structures are lighter weight and easier to use than traditional steel tanks.



The Forage Component

Selection & establishment

All forage species should be adapted to the site conditions, which may change throughout the property. Select forage species that can tolerate the low soil pH that is most amenable to pine production. When possible, choose native, non-invasive forage species.

Establishment of forage in a silvopasture system is not significantly different from accepted establishment practices in an open pasture. The important steps of site preparation, seeding rates, planting depth, and acquiring adapted, high quality seed or sprigs do not change in a silvopasture system. Soil amendments and fertilizer applications need to take into account requirements and limitations of both forage and tree components. In addition, the selection and application of herbicides merits additional caution to avoid damaging the silvopasture crop trees. Newly planted seedlings are particularly susceptible to herbicide drift and stress from broadleaf herbicides.

Some forage species tend to be lower in fiber and more digestible when grown in a tree-protected environment. Nutritional quality varies depending upon parts of the plant selected by livestock.

Characteristics of common forage species

Bermudagrass	Relatively easy to manage
Endophyte friendly/free fescue	High quality desirable winter forage
Orchardgrass	High quality desirable winter forage
Bahiagrass	Brood cow maintenance, fair hay
Hybrid bermudagrass	Versatile
Eastern gamagrass	Moist and fertile site required, highly productive
Small grains	Spring supplement, growing cattle
White clover	pH mid 6+, increase forage quality, nitrogen fixer
Sub clover	Fertile sites, shade tolerant
Crimson clover	Nitrogen fixer
Native warm season grasses	Brood cow maintenance

Management

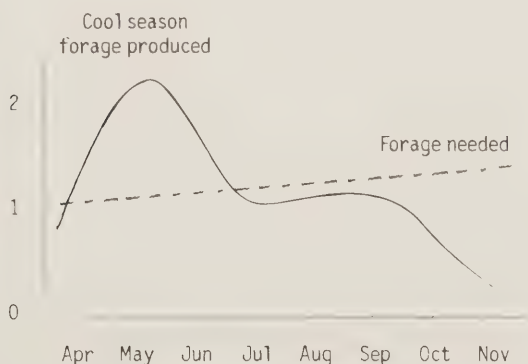
The best way to meet a ruminant animal's nutrient requirements is through the use of a well-managed forage program. The entire concept of silvopasture fits very nicely with the principles of a good forage management program.

In order for this program to be successful, the animals have to be controlled and allowed to graze only in the areas that are appropriate for that specific time. Research conducted at the University of Georgia demonstrated the effectiveness of intensive rotational grazing in improving the efficiency of forage utilization. They showed that stocking rate increased 38 percent, total calf gain per acre increased 37 percent, and rotational grazing required 32 percent less hay. There was not a statistical difference in the calf weaning weight and cow pregnancy rate.

Seasonal acreage allocation

Generally speaking, cool season grasses (during their season of use) are higher in quality but lower in total biomass produced. To maximize grazing, a general guide is to plant about 1 acre of warm season grasses

Livestock demand (animal units) versus forage growth (pounds of dry matter per acre) and availability during the grazing season where livestock were placed on pasture April 1.



Examples of cool and warm season forages

cool season		warm season	
ANNUAL	PERENNIAL	ANNUAL	PERENNIAL
Wheat	Tall fescue	Corn	Bermudagrass
Rye	Orchardgrass	Sorghum	Bahiagrass
Oats	Legumes	Pearlmillet	Dallisgrass
Ryegrass		Sudangrass	Johnsongrass
Legumes			Switchgrass
Crimson clover			Eastern gamagrass
White clover			Big bluestem
			Indiangrass

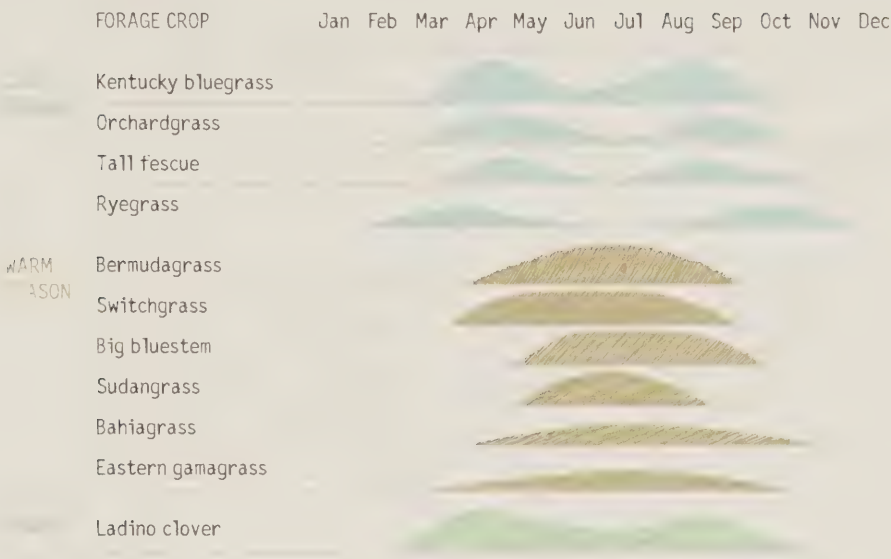
for every 2½ to 3 acres of cool season grasses. Of course, your geographic location also is very important. So, in the Northern United States, cool season grasses would receive much more weight, and in the deep south, warm season forage may make up a larger portion of the grazing system.

The growth period for warm season grasses is different than cool season. Cool season forages generally produce most of their growth in the spring, with a smaller period of production in the fall. This varies by species, so it is important to know the growth period of the species being managed. Warm season forage growth generally occurs between April and October, but also varies by species, with some species making maximum growth very fast and not producing much later in the summer; others begin their growth later and extend it farther into late summer or early fall.

If a crop other than hay is to be managed between tree rows (alley cropping), appropriate management considerations must be made, such as suitable width of alleys (for planting/harvesting equipment), chemical compatibility of herbicides, pesticides, etc.

There is no "all-season" plant available that can be effective as forage year-round. Producers must recognize the limitations of plant seasonality as well as take advantage of its benefits. Forage systems that incorporate both cool and warm season pastures can provide grazing nearly year-round.

Pasture production patterns



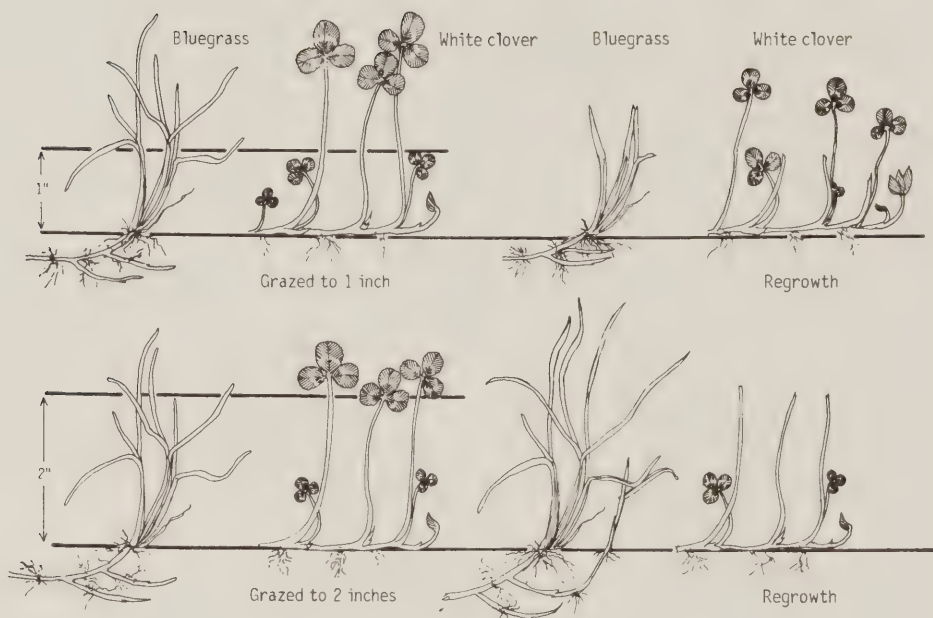
Low growing plants, like common bermudagrass, bahiagrass, or white clover, can withstand close late-season grazing since they hold some leaf area close to the ground and have carbohydrate reserves in their stems and rhizomes. On the other hand, orchardgrass, johnson-grass, and most native grasses have less leaf area after close grazing, and contain most of their carbohydrate reserves in the stem bases.

Forage regrowth

Perennial forage plants must have stored energy to survive the dormant season and begin growth again. The last cutting of forage or pasture should be timed to allow adequate regrowth and carbohydrate storage prior to a killing frost. This ensures forage quality for the following year.

Forage regrowth initiation period as a rule of thumb is generally 3 to 7 days but is highly variable depending upon species, time of year and growth period, temperature, and moisture.

There are a number of options and formulas for determining total number of pasture areas to establish an optimal number of grazing units/pastures. However, most systems will have between 8 to 10 pastures. The



number of grazing units depends on plant recovery time (i.e., the rest period needed for specific vegetation), the livestock species being allowed to graze/browse, the final goal of livestock production (milk vs. meat), and the classes of stock utilizing the vegetation.

Here are some rules of thumb:

Grazing periods

- The faster the growth, the shorter the graze period
- Three to five days maximum for spring
- Five to nine days maximum for early summer
- Nine to 12 days for late summer
- Five to nine days for fall

It is important to recognize that forage species respond differently to grazing pressure. For example, bluegrass and white clover recover differently to grazing heights of 1 inch and 2 inches. White clover recovers more rapidly than bluegrass when grazed to a 1-inch height. The reverse occurs when grazed to a 2-inch height.

Recommended grazing height and recovery periods

FORAGE CROP	TARGET HEIGHT (inches)		USUAL DAYS REST FOR RECOVERY OF LEAF AREA
	BEGIN GRAZING	END GRAZING	
Alfalfa (grazing types)	10-16	2-3	15-30
Bahiagrass *	6-10	1-2	10-20
Bermudagrass	4-8	1-2	7-15
Big bluestem *	15-20	10-12	30-45
Clover, white and sub	6-8	1-3	7-15
Clovers, all others *	8-10	3-5	10-20
Dallisgrass	6-8	3-4	7-15
Eastern gamagrass *	18-22	10-12	30-45
Tall fescue	4-8	2-3	15-30
Indiangrass *	12-16	6-10	30-40
Johnsongrass	16-20	8-12	30-40
Orchardgrass *	8-12	3-6	15-30
Ryegrass, annual	6-12	3-4	7-15
Sericea lespedeza *	8-15	4-6	20-30
Small grains	8-12	4	7-15
Switchgrass *	18-22	8-12	30-45

Remember that perennial grasses must have stored energy to survive the winter, to begin growth in the spring, and to recover after complete defoliation.

For optimizing animal performance

- Dairy cattle should be moved one to two times per day.
- Stocker cattle should be moved every 1 to 2 days. In some cases, livestock may need to be moved every half day.

Resources



Silvopasture establishment & management: step-by-step

Initial planting of triple rows of southern pine into existing pasture lands. Prepare site by tilling or with herbicide use. The area between triple-row sets can be hayed or cropped during establishment years. Once trees reach 5 to 6 feet, cattle can be allowed in for managed grazing.



Pruning when trees reach around 15 feet in height increases available light for forage production and leads to the production of high quality wood.



Continue periodic pruning until a desired branch-free trunk or clear length is achieved. The preferred clear log length is 18 feet, however this may vary depending on local markets.



Trees can be thinned beginning 12 to 15 years of age and every 5 to 7 years when necessary. However, this depends greatly on initial stocking. For example, larger spacing with wider alleys may not need thinning.



Generally, enough trees are removed at each thinning to maintain sufficient sunlight for forage—if only 150 to 200 trees were initially planted, there might only be 100 trees per acre left at harvest.



A well-designed and managed system makes for easier and more efficient harvest of sawtimber logs.



Converting a forest into a silvopasture system

When starting from a pine plantation, the stand is thinned to reduce stand density and open the canopy to about 30 to 35 percent to establish the forage. This is variable depending upon the species of grass. Cool season grasses can tolerate greater canopy cover than warm season grasses.



After thinning, a prescribed burn is conducted to clean up debris.



Following burning and debris removal, forage is established using standard grass establishment techniques. Ideally, the stand should be disked for the sprigging of grasses or forage. Tillage options should take care not to damage root structure or trees.



Online resources

USDA National Agroforestry Center (NAC)

<http://www.unl.edu/nac/silvopasture.htm>

Auburn University

<http://www.ag.auburn.edu/agrn/silvopasture/silvopastureindex.htm>

The Center for Subtropical Agroforestry

<http://cstaf.ifas.ufl.edu/research5.htm>

University of Missouri Center for Agroforestry

<http://www.centerforagroforestry.org/practices/sp.asp>

Association for Temperate Agroforestry (AFTA)

<http://www.aftaweb.org/entserv1.php?page=2>

TreeSearch

<http://www.treesearch.fs.fed.us/>

Appalachian Farming Systems Research Center—USDA Agricultural Research Service

<http://www.ars.usda.gov/pandp/people/publications.htm?personid=1685>

Dale Bumpers Small Farm Research Center—USDA Agricultural Research Service

http://www.ars.usda.gov/research/projects/projects.htm?accn_no=412583

Silvopasture in the Southeast Blog

<http://silvopasture.blogspot.com/>

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Glossary

Agroforestry	The intentional combination of agriculture and forestry to create an integrated and sustainable land use system. Agroforestry takes advantage of the interactive benefits of combining trees and shrubs with crops and/or livestock.
Bare-root seedlings	Tree seedlings that are produced in nursery beds without the use of containers. These seedlings are dug and sold without soil around their root systems. Bare-root seedlings must be planted as soon as possible.
Bole	The trunk of a tree.
Break grazing	The division of a small area of a larger paddock with temporary fence for managing grazing and forage recuperation.
Carrying capacity	The maximum stocking rate for livestock to maintain or improve vegetation and resources on a parcel of land. Carrying capacity is variable due to fluctuations of forage production.
Densiometer	A device used to measure the amount of canopy closure.
Endophyte-free fescue	Fescue that is not infected with the endophyte fungus that has been associated with poor weight gains and lowered conception rates of cattle, reproductive problems in horses, and poor milk production in dairy animals. Established fescue can be tested to determine the presence of the fungus and it is recommended that infected areas be treated and replanted with endophyte-free fescue to improve herd quality.
Forage	Vegetation browsed or grazed by livestock.
Forage allocation	The process of dividing forage resources among livestock for different dietary needs. Forage allocation depends on the type of forage available, the carrying capacity of the site, and the seasonal needs of the type of livestock using the site. Forage allocation for calves will be different than for non-lactating cows.

Fusiform rust	A fungus that can occur on the main stem of pine seedlings that often causes mortality and/or stem weakness. Fungus produces orange spores and galls.
Grass-finished	Livestock that feed only on grass or natural forage their entire lives.
Grazing capacity	Similar to carrying capacity , grazing capacity is the total number of livestock which may be grazed within a given area based on total forage resources available.
Herd effect	The impact of a concentrated herd of livestock on soil, water, and vegetation resources on a site. Dense herds often lead to soil compaction, erosion, and other undesirable effects on a site.
Joule	The actual quantity of energy that passes through an animal in an energized fencing system.
Paddock	A fenced area used to confine livestock to a particular area.
Pruning	The removal of side branches and/or multiple leaders from trees. Pruning is carried out to improve the market value of the final wood product by producing knot-free wood for the improvement of timber quality.
Pugging	The compaction, trampling, and site disturbance associated with overgrazing of livestock within a particular area. While generally not a recommended practice, pugging can be used to “overgraze” an area to remove undesirable vegetation as a method of site preparation.
Ripping	The practice of subsoiling using a specialized blade or “ripper” to break up and aerate compacted soils.
Scalping	The site preparation practice of mechanically peeling back sod or using herbicides to remove competition for the planting of trees.

Stock density	The actual number of animals on a given paddock or area of land. Different than stocking rate .
Stocking rate	The number of specific types of livestock allowed to graze or browse a unit of land for a specified time period. Stocking rates are typically expressed as the number of acres required to maintain one full-grown animal throughout all or part of a year.
Strip grazing	The practice of frequently moving a temporary fence to subdivide a paddock into smaller grazing units. Strip grazing is often used to seasonally ration or utilize forage resources.
Voltage	In considering the voltage necessary to deter livestock, a minimum level of voltage is required to overcome the resistance of the animal's skin, fence, wire, and soil. Voltage delivered can be reduced by energy "leakage" through dew, grass, etc. Thus, an animal's nose is more sensitive than its hide, as there is less resistance. It is important to consult an energized fencing supplier or livestock specialist in designing and implementing an energized fencing system.

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